CHAPTER 12

BOILERS

The most common type of boiler in the NCF is the scotch marine. "Scotch marine" is a generic term that identifies a boiler with a furnace, which forms an integral part of the boiler assembly. This configuration allows for compact construction requiring only a small space for the capacity produced. Scotch marine boilers are package units consisting of a pressure vessel, burner, controls, draft fan, and other components assembled into a fully factory fire-tested unit. This provides an engineered unit equipped for quick installation and connection to services. As a first class petty officer, you will supervise personnel in the installation, operation, and maintenance of boilers. As a chief petty officer, you will be responsible for the general management of these plants. This chapter provides insight into many skills that you must develop to be a proficient supervisor/manager of a boiler plant.

INSTALLATION OF BOILERS

When you are preparing to install a boiler, consider three basic factors-site location, accessories, and fittings. This section discusses each of these items. Proper installation of a boiler helps to ensure succesful operation. Always refer to the manufacturer's manuals, and follow your prints and specifications closely. By being thorough in your planning and execution of plans, you can prevent many future problems for operators and maintenance personnel.

SITE LOCATION

Give careful consideration to site location for the construction of a boiler plant. Primarily, the cost in materials, manpower, and equipment is the most important factor effecting this selection. These costs can usually be reduced by locating the plant site as close as possible to the largest load demand facility, such as a galley or laundry.

Location

When selecting a site for boiler installation, you must consider the availability of the following:

- Water
- Electricity
- Fuel
- Natural site drainage

Attempt to avoid high pedestrian and vehicle traffic areas for safety reasons. Another item to consider is noise level. Noise pollution may cause discomfort for personnel, especially if the site being considered is adjacent to a berthing area.

These are factors you must consider when you become involved in selecting a boiler plant site. Each situation may include all, part, or more than these factors. You must look at each installation and evaluate the needs of that job.

Boiler Foundation

Constructing the foundation or platform a boiler sits on requires skilled engineering and development. Follow the manufacturer's specifications. Boilers may vary in wet weight from 1.5 tons to more than 20 tons. A substantial foundation that can withstand the weight and absorb vibration is essential.

Reinforced concrete slabs with runners provide for placing and anchoring the boiler. The runners should provide a level, uniform support and be of sufficient height to allow for maintenance and the installation of piping under the boiler. A raised platform also provides easier access for boiler room cleanup.

Generally, a sump in the slab between the runners provides a catchment area for boiler blowdown or draining of the boiler. This sump drains from the building to a suitable dispersal point.

Boiler Room

When considering the requirements of sheltering a boiler, you must ensure there is enough room for the boiler and all of the accessory equipment. This accessory equipment may include condensate tanks and pumps, chemical feeders, water makeup tanks and feeders, and blowdown tanks.

The boiler room must also be large enough to allow for boiler maintenance, for retubing, and for removing and replacing the boiler. The tube length of a boiler maybe from 2 feet 6 inches to at least 10 feet, and possibly longer. To simplify the removal of the tubes, ensure the boiler room is long enough or have a door located behind the boiler. The most important thing to check is the manufacturer's specifications, which provides the proper dimensions for locating the boiler.

Fresh air inlets and louvers allow fresh air to enter and move across the boiler area. This fresh air entering the boiler room removes excess heat and provides adequate makeup air for combustion.

When planning for boiler room construction, you must always consider boiler requirements, maintenance requirements, and manufacturer's recommendations.

ACCESSORIES

As you review table 12-1, open the fold out figure 12-1 on page 12-5 for identification of the boiler accessory equipment.

Table 12-1.—Boiler Accessories

	ACCESSORY	LOCATION	PURPOSE	SPECIAL REQUIREMENTS
1	Boiler	Boiler room	Generate steam or hot water in a closed vessel	
2	Main steam stop	On the steam outlet of a boiler	Place the boiler on line or off line	Must be outside yoke rising spindle type if it is over 2". This allows the operator to distinguish the position of the valve by sight
3	Guard valve	On the steam outlet of a boiler directly following the main steam-stop valve	Guard or backup to the main steam-stop valve	When two or more boilers are connected to a common header, the steam connection from a boiler with a manhole opening must be fitted with a main steam-stop and a guard valve
4	Daylight (drain) valve	Between the main steam-stop valve and the guard valve	Open only when the main steam and guard valves are closed. Indicates if one of the valves is leaking through	When both the main steam-stop and guard valves are required, install a daylight drain valve

Table 12-1 (Continued).—Boiler Accessories

	ACCESSORY	LOCATION	PURPOSE	SPECIAL REQUIREMENTS
5	Main steam line	The line that conveys steam from a boiler to all branch or distribution lines. When a system is supplied by a bank of boilers connected into the same header, the line(s) conveying steam for the boiler(s) to the header	Carry steam from the boiler to the branches or distribution lines	Pitch horizontal piping 1/4" per 10'. Do not use galvanized piping
6	Root valve	Installed in branch or distribution lines just off of the main steam line	Isolate a branch or distribution line (serves as an emergency shutoff)	Normally of gate-valve design, fully opened or closed
7	Pressure regulating valve (PRV)	Installed as close as practical (after a reducing station) to the equipment or area it serves	Equipment that requires lower pressure than main steam line pressure (coppers,dishwashers, steam chests, turbines, etc.)	
8	Steam trap	Installed on the discharge side of all steam heating or cooking equipment, dead ends, low points, or at regular intervals throughout a steam system (automatic drip legs)	Automatically drains condensate and prevents the passage of steam through equipment	Install traps with unions on both sides for easy replacement. Inlet and outlet piping of trap needs to be equal or larger than trap connections
9	Drip legs	Provided throughout a system where condensation is most likely to occur, such as low spots, bottom of risers, and dead ends	Remove condensate from a system manually	Place at intervals of not over 200' for horizontally pitched pipe and at intervals of not over 300' for buried or inaccessible piping
10	Temperature regulating valve (TRV)	Install in the steam supply line close to equipment needing temperature regulation (sensing element is installed at a point where the temperature is to be controlled, such as the hot-water discharge side of a heat exchanger	Control steam flow through a vessel or heating equipment	When the valve throttles to a partially closed position, the pressure in the equipment can easily go into a vacuum. This is caused by condensing steam and it holds condensate in the equipment. Use a vacuum breaker to solve the problem
11	Heat exchanger	Locate as close as practical to the source for which it is going to supply heated water or oil	An unfired pressure vessel that contains a tube nest or electrical elements. Used to heat oil or water	
12	Strainer	Install in steam and water lines just ahead of PRVs, TRVs, steam traps, and pumps	Prevent malfunctions or costly repairs to equipment and components by trapping foreign matter, such as rust, scale, and dirt	

Table 12-1 (Continued).—Boiler Accessories

	ACCESSORY	LOCATION	PURPOSE	SPECIAL REQUIREMENTS
13	Condensate line	Return line extends from the discharge side of steam traps to the condensate/makeup feedwater tank	Carry condensed steam back through piping for reuse in the boiler or heating vessel	Pitch lines toward boiler 1/4" per 10'. Do not use galvanized piping
14	Condensate/ makeup tank	Close to the boiler as practical and at a higher level than the boiler feed-pump suction line	Provide storage space for condensate and makeup/feedwater and vent noncondensable gases to the atmosphere	
15	Feed pump	Supplies water to the boiler as required	Installed between the condensate/makeup/feedwater tank and the boiler shell or steam drum	Pump must be capable of pumping higher pressures than that of the boiler pressure
16	Feedwater pipe	This line extends from the discharge side of the feedwater pump to the boiler shell or drum (installed below the steaming water level)	Provide feedwater to the boiler when required	Place relief valve, check valve, and stop valve in the feedwater pipe
17	Relief valve	Between the feed pump and the nearest shutoff valve in the external feed line	Relieve excessive pressure should the external feedline be secured and the feed pump started accidently. A ruptured line or serious damage to the feed pump could occur if there were no relief valve	Relief valve opens gradually at a set pressure. Safety valves open fully at a set pressure. Do not use a relief valve in place of a safety valve
18	Feed check valve	Between the feed pump and the stop valve in the feed-water pipe	Prevent backflow from the boiler through the feedwater line into the condensate/ feedwater tank during the off cycle of the pump	Ensure installation of valve is set in the roper direction for its intended purpose
19	Feed stop valve	In the feedwater line as close to the boiler as possible between the boiler and feed check valve	Permit or prevent the flow of water to the boiler	If a globe valve is used, you must install the valve so as to enter (pass through) the valve under its disk

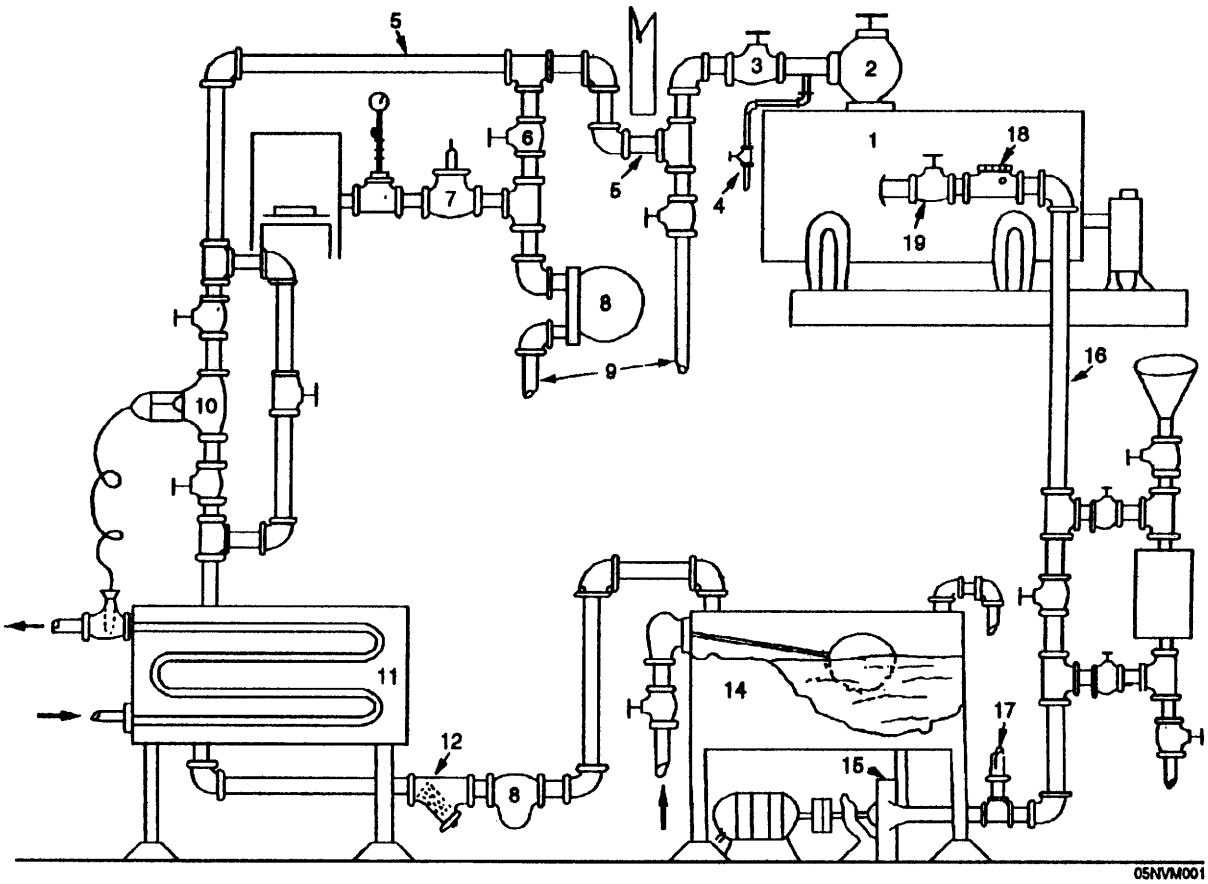

Figure 12-1.—Boiler accessary equipment.

FITTINGS

Before reading table 12-1(A), open the fold out on page 12-9(A) and refer to figure 12-2 and 12-3.

Table 12-1(A).—Description of Boiler Fittings

	FITTING	LOCATION	PURPOSE	ASME CODE REQUIREMENTS
1	Air cock	Installed in the uppermost steam space connected to the boiler shell or steam drum	Permit air to escape when filling boiler with water during the initial building of steam. It allows air to enter the boiler when being drained	Open valve when a boiler is initially filling with water during steam buildup and when emptying a boiler
2	Water column	Installed either on a boiler shell or steam drum adjacent to the steaming water level	Steady the water level in the gauge glass and serve as a sedimentation chamber to minimize obstruction of the small diameter gauge glass connections	Column must be connected to the steam and water space with a minimum size pipe and fittings of 1 inch and that each right angle turn be made with a cross to aid in inspection and cleaning. See figure 12-3
3	Water column blowdown line and valve	From the bottom of the lower cross on the water column to either a bilge, tank, or blowdown pit. Valve is installed just below the column in the blowdown line	The line and valve permit removal of scale and sediment from the water column	Minimum permissible size for the blowdown piping and valve is 3/4"
4	Gauge glass	Located at the steaming water level. Attached to steam drum, water column, or boiler shell	Visual means of checking the water level being maintained within a vessel	Minimal size of gauge glass is 1/2". Boilers operating at 400 psi of pressure or greater require two gauge glasses and the lowest visible portion of the gauge glass must be at least 2" above the lowest permissible water level
5	Gauge glass shutoff valves	Installed on the upper and lower ends of a gauge glass	Permit an indirect connection of the glass to the water column, boiler shell, or steam drum. The valves also serve as a means for isolating the gauge glass from the steam and water for repairs	Gauge glass shutoff valves have a minimal size of 1/2". Some valves may be fitted with an automatic shutoff device, usually consisting of a nonferrous ball that functions to secure or prevent the escape of steam or hot water should the gauge glass break
6	Glass blowdown line and valve	The line from the bottom of the gauge glass to the blowdown pit, bilge, or tank	Permit the operator to detect a partial gauge-glass blockage manually	When under pressure and gauge glass blowdown line is opened and then closed, the water level should return promptly. If level returns slowly, a partial blockage may be present

Table 12-1(A) (Continued).—Description of Boiler Fittings

	FITTING	LOCATION	PURPOSE	ASME CODE REQUIREMENTS
7	Try cocks	Located on water column, boiler shell, or steam drum. If only two cocks are used, they are slightly above and below the steaming water level. If three are used, they are above, below, and at approximate steaming level	Prove the water level in a vessel and check the accuracy of a gauge glass	Boilers not exceeding a diameter of 36" or heating surface of 100 square feet need only two try cocks and one gauge glass. Boilers that exceed the above require three try cocks regardless of the number of gauge glasses
8	Pressure gauge	Installed in a well-lighted area and connected to some boilers uppermost steam space	Indicate the amount of pressure within a vessel	Dial on gauge is graduated so it reads approximately twice the pressure at which the safety valve is set to open. Test every 6 months or whenever you doubt the accuracy of the gauge
9	Fusible plugs	Fire-actuated and steam-actuated plugs are located at the lowest permissible water level. Normally screwed into rear tube sheet above highest row of tubes	Operator warning device of low-water condition. At 450°F the tin is melted out of the plug and the steam escaping causes a whistling sound	Must be replaced every year
10	Bottom blowdown piping	Piping connected to the bottom of the boiler and extending to a bilge, tank, or blowdown pit	Remove sediment, sludge, excessive chemicals, and water from the boiler	Minimum size blowdown and fittings for boilers having 100 square feet or less of heating surface require 3/4" pipe and fittings. If boiler is in excess of 100 square feet, 1" is the minimum and 2 1/2" is the maximum
11	Bottom blowdown valves	Located in the bottom blowdown line. If a quick closing valve is installed, it will always be installed as the first valve in the line coming from the boiler	Remove water, sludge, sediments, and chemicals from the boiler. May have two valves in-line	Every boiler must have one slow opening valve. A slow opening valve requires at least five complete 360° turns between fully opened and closed positions. Boilers exceeding 100 psi must provide two bottom blowdown valves. One may be of the quick closing type. When using the blowdown line, remember to always open the quick closing valve first and secure it last
12	Safety valve	Installed in the uppermost steam space of a boiler	Prevent pressure within the boiler from increasing beyond the safe operating limit	No other valve is permitted to be between the safety valve and the boiler. Every boiler must have at least one. If heating surface is over 500 square feet, two safety valves are required. Lift valves monthly to blow away dirt and prevent disk from sticking. Ensure boiler pressure is at 75% of valve pop setting for removal of debris, and ensure the valve will re-seat
13	Handhole plates	Elliptical- or round-shaped plates located at various locations on a boiler, depending on design	Provide visual hand-arm inspection for waterside maintenance, inspection, and repair work	

Table 12-1(A) (Continued).—Description of Boiler Fittings

	FITTING	LOCATION	PURPOSE	ASME CODE REQUIREMENTS
14	Manhole plates	Eliptical-or round-shaped plates that are 5 to 6 times as large as handholes plates	Provide for body entrance into boiler watersides for , inspection, maintenance, and repair work	
15	Access door	Located near the combustion chamber. Some are located on the bottom of the combustion chamber	Provide access to the combustion chamber and firesides of a boiler for inspection, maintenance, and repair work	
16	Breaching	Located at a point where the combustion gases leave the boiler and extend to where the stack begins	Allow for expansion and contraction	
17	Stacks	Located at the end of the breaching and extends to the atmosphere	Remove products of combustion from the combustion chamber to the atmosphere. Also stacks provide draft which aids combustion	Stacks are required to be high enough to comply with health requirements

INSPECTING AND TESTING RESPONSIBILITY

The commanding officer of the cognizant activity ensures that the boilers and unfired pressure vessels installed at their facility are certified. Inspection and testing of boilers and unfired pressure vessels are done by a boiler inspector certified by NAVFACENGCOM and/or licensed by the cognizant NAVFACENGCOM Engineering Field Division (EFD). This inspector is on the rolls, except for the following:

- Inspection responsibility has been assigned to the commanding officer of a Public Works Center.

- The commanding officer of a major or lead activity is responsible for doing the maintenance of public works and public utilities at adjacent activities.

- It is impractical to use qualified personnel for such inspections because of the limited work load. In such situations, assistance for inspection services should be obtained by an EFD inspector or an activity inspector located near the requested activity which has qualified personnel or by contract. When assistance is required by the EFD, such assistance is on a reimbursable basis. The requesting activity is responsible for providing the finds to accomplish the inspections

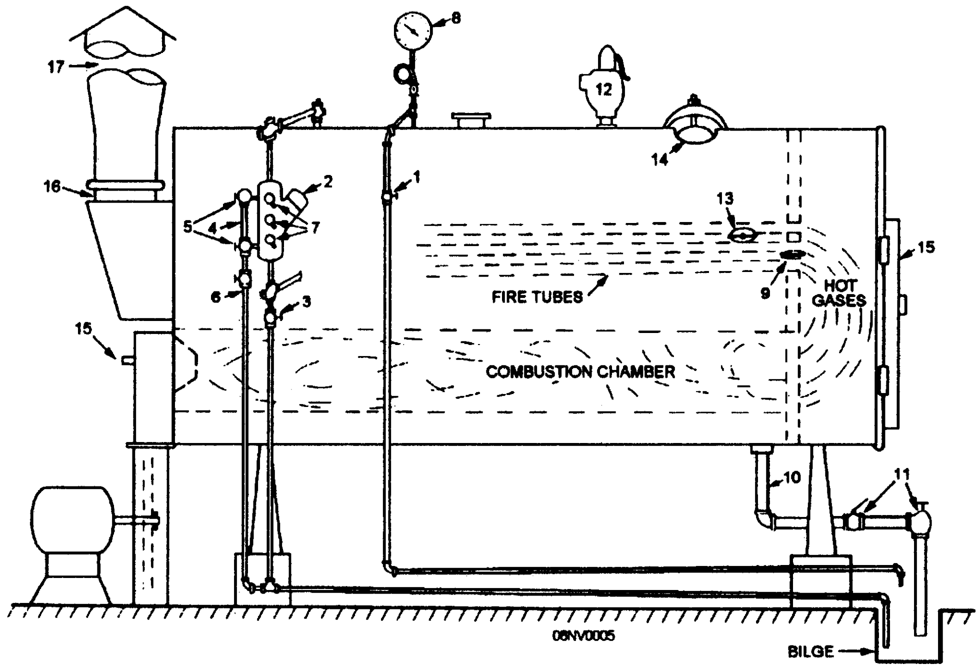

Figure 12-2.—Boiler fittings.

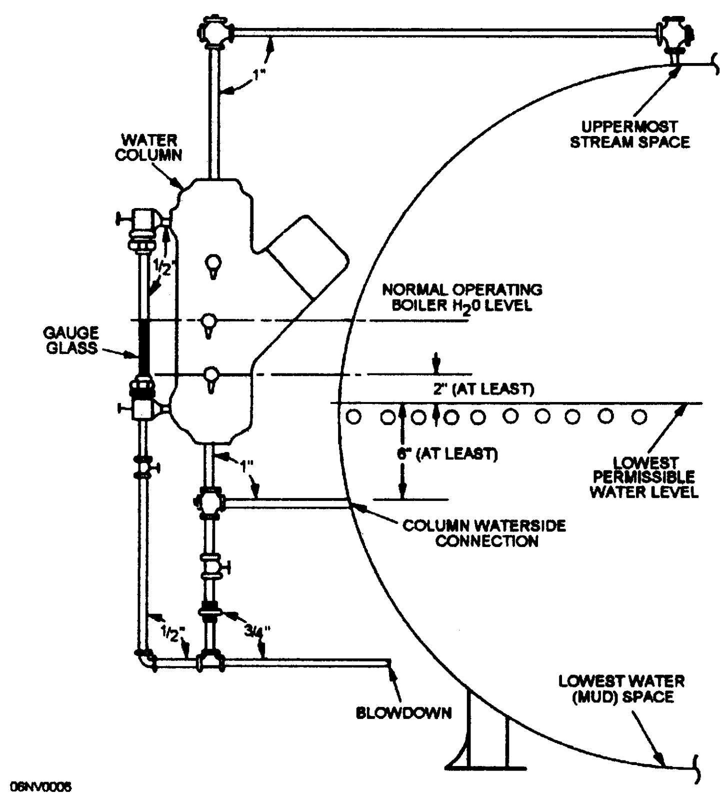

Figure12-3.—Water column.

FREQUENCY OF INSPECTION AND TESTS

The following chart lists different types of equipment and the frequency of boiler testing requirements. For frequency and testing requirements concerning unfired pressure vessels, refer to NAVFAC MO-324.

Table 12-1(B).—Boiler Inspection and Test Frequencies

ITEM	INTERNAL INSPECTION	EXTERNAL INSP. AND OPERATIONAL TESTS	HYDROSTATIC TESTS
Boilers; wet or dry lay-up	At least annually. At resumption of active service.	At least annually. At resumption of active service.	Tightness test at resumption of active service.
Boilers; heating and LTW LTW boilers within at least once every 3 years if output is less than 5 million Btuh	At least annually. After any repair or alteration of pressure parts.	At least annually. After any alteration or modification to boilers, control equipment, or auxiliaries.	Strength test at least once every 6 years. Tightness test all other years. Strength test after repair or alteration of pressure parts. Additional times at the discretion of the inspector.
Boilers; power, high pressure, HTW, and MUSE	At least annually. After repair or alteration of pressure parts.	At least annually. After any alteration or modification to boilers, control equipment, or auxiliaries.	Strength test at least once every 3 years. Tightness test all other years. Strength test after repair or alteration. Additional times at the discretion of the inspector.

Notes:

1. Additionally, MUSE boilers and other portable boilers must be inspected externally and internally and certified each time they are moved from one place to another. A MUSE steam coil type of boiler is exempt from annual inspections while in dry or wet lay-up.

2. All manhole and handhole gaskets must be replaced after a strength test unless they are made of non-compressible steel.

PREPARING FOR INSPECTION

The activity that operates and maintains pressure vessels provides all of the material and labor required to prepare the vessels for inspection. You need to help the inspector during inspection. An inspection on pressure vessels located on a naval base in a foreign country must comply with NAVFAC MO-324, *Inspection and Certification of Boilers and Unfired Pressure Vessels.*

WATERSIDE INSPECTION OF BOILER TUBES

Regular waterside inspection of boiler tubes provides the information required to determine the effectiveness of water treatment, maintenance procedures, diagnoses of boiler operating troubles, and in general an overall condition of the boiler.

Tube failures generally occur in the outer half of the tube nest from external corrosion just above the water drum. When such failures have occurred, either in operation or under

hydrostatic test, or when the examination of tubes in the exploring block shows that the tube thickness is less than half the original thickness, complete renewal must be made of all tubes from the center row to the outer row (inclusive) over a fore-and-aft length of the tube bank sufficient to completely cover the affected area. This renewal must be made regardless of the condition of the tubes that were not included in the exploring block.

The existence of slight, scattered pitting does not necessarily require the complete retubing of the boiler, even if the thickness of the tubes at some of the pits is less than 50% of the original tube thickness. When pitting is observed, tubes should be split and examined to see whether the pitting is (1) moderately heavy, and (2) general throughout the boiler.

Internal pitting resulting from improper treatment of boiler water is most likely to occur in tubes that receive the most heat (screen tubes, fire row tubes, and so forth) and in areas that are particularly subject to oxygen pitting. In general, oxygen pitting tends to occur most commonly in downcomers, in superheaters, and at the steam drum ends of generating tubes. If active oxygen pits (that is, pits that are still scabbed over, rather than clean) are found when the boiler is inspected, or if oxygen pitting is suspected because of the past operating history of the boiler, one or two tubes should be removed from the areas in which oxygen pitting is most likely to be found.

The tubes thus removed should be split and examined. If as many as 25% of the pits are deeper than 50% of the tube wall thickness, and if at least a few of the pits are deeper than 65% of the tube wall thickness, a sample of about 20 tubes from the screen and last rows of the generating bank should be cut. These tubes should be split and examined, and their condition should be evaluated on the same basis as before. If as many as 25% of the pits are deeper than 50% of the wail thickness, and if at least a few are deeper than 65%, the oxygen pitting is considered to be general throughout the boiler and moderately heavy. With these findings, complete tube renewal should certainly be considered. However, it is possible that complete tube renewal may be postponed in some cases if (1) the boiler can be successfully cleaned by a chemical cleaning, (2) the boiler can successfully withstand a 125% hydrostatic test, and (3) future boiler water treatment, use of blowdown, and laying-up procedures can be expected to be in strict accordance with NAVFAC requirements.

Before you make a detailed waterside inspection of boiler tubes, you should be familiar with some of the WATERSIDE CAVITIES and SCARS that can be recognized by visual examination.

LOCALIZED PITTING is the term used to describe scattered pits on the watersides. These pits are usually—though not always—caused by the presence of dissolved oxygen.

WATERSIDE GROOVES are similar to localized pits in some ways, but they are longer and broader than the pits. Waterside grooves tend to occur in the relatively hot bends of the tubes near the water drum; they may also occur on the external surfaces of desuperheater tubes. Some waterside grooves are clean, but most contain islands of heavy corrosion scabs. A typical example of waterside grooving is shown in figure 12-4.

CORROSION FATIGUE FISSURES are deep-walled, canyon-like voids. They have the appearance of being corroded, rather than fractured, and they may be filled with corrosion products. These fissures occur in metal that has been fatigued by repeated stressing, thus making it more subject to corrosion than it would other-wise be.

GENERAL WATERSIDE THINNING can occur if the boiler water alkalinity is too low over a long period of time, if the boiler water alkalinity is too high, or if acid residues are not completely removed from a boiler that has been chemically cleaned. The greatest loss of metal from general waterside thinning tends to occur along the side of the tube that is toward the flame. The entire length of the tube from steam drum to water

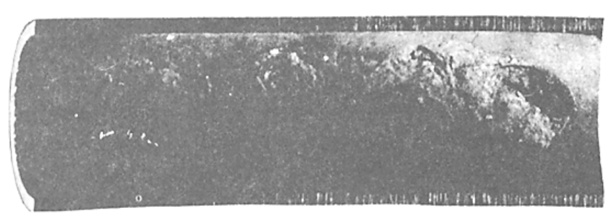

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Figure 12-4.—Waterside grooving in a generating tube.

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Figure 12-5.—General waterside thinning.

drum may be affected. Figure 12-5 shows general waterside thinning.

WATERSIDE BURNING may occur if the temperature exceeds about 750°F in plain carbon steel tubes or about 1,000°F in most alloy superheater tubes. The effect of waterside burn-ing is the oxidation of the tube metal to a shiny, black, magnetic iron oxide known as high-temperature oxide.

WATERSIDE ABRASION is the term used to describe waterside cavities that result from purely mechanical causes rather than from corrosion. For example, tube brushes or cutters may cause abrasion spots at sharp bends in economizer, superheater, and generating tubes. The surface markings of such abrasions indicate clearly that they result from mechanical abrasion rather than from corrosion.

DIE MARKS appear as remarkably straight and uniform longitudinal scratches or folds on the watersides of the tube. They are the result of faulty fabrication. Die marks, shown in figure 12-6, may extend for the full length of the tube. Localized corrosion occurs quite often along the die mark.

TUBE CORRUGATION is a peculiar type of heat blistering that occurs when the boiler water is contaminated with oil. Corrugation may consist of closely spaced, small-diameter, hemispherical bulges, as though the tube metal had been softened and then punched from the inside with a blunt instrument. It may also exist as a herring-bone or chevron pattern on the tube wall nearest the flame, as shown in figure 12-7. It is not known exactly why oil contamination of the boiler water tends to cause this patterned corrugation.

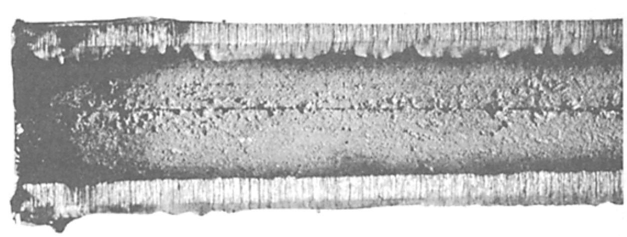

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Figure 12-6.—Die marks on the waterside of a tube.

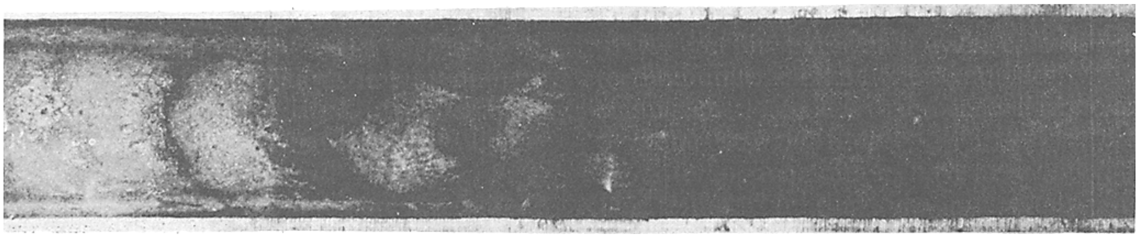

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Figure 12-7.—Tube corrugation resulting from oil on waterside.

Waterside Inspection of Drums and Headers

Whenever a boiler is opened for cleaning and overhaul, the internal surfaces of the drums and headers should be carefully inspected for evidence of cracking. Particular attention must be given to steam drum manhole knuckles, knuckles at corners of drum heads, corners of cross boxes and headers, superheater header vent nozzles, and handhole openings. Any defect found must be recorded in the boiler water treatment log and in the maintenance log. These defects should also be reported to the maintenance office so that appropriate repair action can be taken.

Hydrostatic Tests

Boilers are tested hydrostatically for several different purposes. In each case, it is important to understand why a test is being made and to use—but NOT to exceed—the test pressure specified for that particular purpose. In general, most hydrostatic tests are made at one of three test pressures: boiler design pressure, 125% of design pressure, or 150% of design pressure. Other test pressures may be authorized for certain purposes. For example, a test pressure of 150 psi is required for the hydrostatic test given before a boiler undergoes chemical cleaning.

The hydrostatic test at design pressure is required upon the completion of each general overhaul, cleaning, or repair that affects the boiler or its parts and at any other time when it is considered necessary to test the boiler for leakage. The purpose of the hydrostatic test at design pressure is to prove the tightness of all valves, gaskets, flanged joints, rolled joints, welded joints, and boiler fittings.

The test at 125% of design pressure is required after the renewal of pressure parts, after chemical cleaning of the boiler, after minor welding repairs to manhole and handhole seats, and after repairs to tube sheets, such as the correction of gouges and out-of-roundness. The “renewal of pressure parts” includes all tube renewals, rolled or welded, except downcomers and superheater support tubes.

The test at 150% of design pressure is required after welding repairs to headers and drums, including tube sheet cracks and nozzle repairs, after drain and vent nipple repairs, and after renewal or rewelding of superheater support tubes and downcomers. The hydrostatic test at 150% of design pressure is basically a test for strength. This test may be (but is not necessarily) required at the 5-year inspection and test.

Before making a hydrostatic test, rinse out the boiler with freshwater. Using at least 50-psi pressure, play the hose onto all surfaces of the steam drum, the tubes, the nipples, and the headers. Examine the boiler carefully for loose scale, dirt, and other deposits. Be SURE that no tools or other objects are left in the boiler. Remake all joints, being sure that the gaskets and the seating surfaces are clean. Replace the handhole and manhole plates and close up the boiler.

Gag all safety valves. Boiler safety valves must NEVER, under any circumstances, be lifted by hydrostatic pressure. When gagging the safety valves, do not set up on the gag too tightly or you may bend the valve stems. As a rule, the gags should be set up only handtight.

Close all connections on the boiler except to the air vents, the pressure gauges, and the valves of the line through which water is to be pumped to the boiler. Be sure the steam-stop valves are completely closed and that there will be no leakage of water through them.

After all preparations have been made, use the feed pump to fill the boiler completely. After all air has been expelled from the boiler, close the air vents and build up the hydrostatic pressure required for the particular test you are making. A hand boiler test pump can be used in building up the hydrostatic test pressure. If you do not have a hand test pump, buildup the required test pressure by continuing to run the feed pump after the boiler has been filled. In any case, be very careful that you do not exceed the specified test pressure. After the boiler is full, it takes very little additional pumping to build up pressure.

To avoid complications arising from changes in pressure caused by changes in temperature, you should use water that is approximately the same temperature as the boiler and the fireroom. In any case, the temperature of the water must be at least 70°F.

While the hydrostatic pressure is being built up, the boiler should be very carefully checked for signs of strain or deformation. If there is any indication of permanent deformation, stop the hydrostatic test and make the necessary repairs. If it is not possible to make the repairs right away, give a second hydrostatic test, progressing slowly up to 20 psi less than the pressure at which the first test was stopped. If the boiler passes this second test successfully, the new working pressure of the boiler must be two-thirds of the test pressure reached on the second test, and all safety valves must be set accordingly.

Do not make any attempt to set up on leaky handhole or manhole plates until the pressure has been pumped up to within 50 psi of the test pressure. After all manhole and handhole leakage has been remedied, pump the pressure on up to test pressure. Check the pressure drop over a period of time. If all valves have been baked off, the maximum acceptable pressure drop is 1.5% of the test pressure over a period of 4 hours. If connected valves are merely closed and left installed, a drop test will not indicate the true condition of the boiler. The pressure drop test is conducted at boiler design pressure.

A tube seat should not be considered tight unless it is bone dry at the test pressure. Any tube that cannot be made tight under a hydrostatic test should be renewed or rerolled.

If there is an excessive pressure drop when there is only a slight leakage at tube joints, handholes, and manholes, the loss of pressure is almost certainly caused by leakage through valves and fittings. Valves and fittings should be overhauled and made tight.

Five-Year Inspection and Test

At 5-year intervals, each boiler must be inspected for integrity of welds and nozzle connections. Lagging must be removed from drums and headers sufficiently to expose the welded joints and the nozzle connections. The welds and nozzle connections must be inspected visually from both inside and outside. If there is any doubt about the welds, they should be inspected by magnetic particle inspection or dye penetrant inspection. If any area, through examination (visual, magnetic particle, or dye penetrant) reveals that a 150-percent boiler design pressure hydrostatic test is warranted, and the area proves to be tight under test pressure, further investigation of the suspected area should be conducted. The investigation should continue until the true condition of the area is known, and if necessary, appropriate repairs are made.

INSPECTION OF FIRESIDES

Boiler firesides should be inspected for signs of damage to the refractory lining, tubes, protection plates, baffles, seal plates, support plates, and other metal parts. This type of inspection is usually conducted when the boiler is secured for fireside cleaning, but it should be conducted each time the boiler is secured.

Refractory Inspection

Frequent inspection of refractories, together with early repair of any weak or damaged places, can do a lot to prevent refractory failure and to postpone the need for complete renewal. It is a good maintenance practice to inspect the refractories every time the boiler is opened up. Such inspections should be very detailed if you have reason to think the boiler has been operated under severe service conditions—steaming at high rates, burning low-grade or contaminated fuel, or undergoing rapid fluctuations of temperature. Severe conditions cause rapid deterioration of refractories and, therefore, increase the need for frequent inspections.

To make a proper inspection of boiler refractories, you should have considerable knowledge of the causes of refractory deterioration. Also, you should know how to tell the difference between serious damage, which may require a complete renewal of brickwork, and less serious damage, which may be dealt with by patching.

Slagging and spalling are two of the main causes of refractory deterioration. Slag is formed when ash and other unburnable materials react with the brickwork. Although the ash content of fuel oil is low, there is always enough present to damage the refractories. The most damaging slag-forming materials are vanadium salts and sodium chloride.

If the slag that forms on the brickwork would remain in place, it would not cause any particular trouble; however, the slag does not remain in place. Instead, it peels off or melts and runs off, taking some refractory with it and exposing a fresh layer of refractory to further slag attack. When deterioration of the brickwork has progressed until only a 3-inch thickness of firebrick remains, the wall should be replaced. When sufficient slag has accumulated on the deck to cause striking with resultant deposits of carbon, the slag should be removed. If less than 1 1/2 inches of firebrick remain after the slag is removed, the entire deck must be replaced.

Another type of slag that results from using fuel oil that is contaminated is usually more damaging than peeling slag. This type of slag is very glassy in appearance, and when this slag melts, it usually covers the entire wall or deck.

Firebrick shrinkage is another cause of furnace deterioration. True shrinkage (permanent shrinkage) is quite rare in firebrick approved for naval use. However, this defect can occur even in approved firebrick. In any case, it is important to recognize the appearance of true firebrick shrinkage because of the extremely dangerous condition it could create if it should occur. When the firebrick shrinks, the hot-face dimensions of each brick become measurably smaller than the cold-face dimensions. This condition leaves an open space around each brick, and the entire wall or floor becomes loose. A wall or floor having this appearance is DANGEROUS and should be completely renewed as soon as possible.

Also, during your inspection, look for signs of unequal stresses that are caused by rapid raising of the furnace temperature while raising steam too rapidly. Emergencies may arise that require the rapid raising or lowering of furnace temperatures, but it is important to remember that the refractories cannot stand this treatment often. As a rule, you will find that raising the furnace temperature too rapidly causes the firebrick to break at the anchor bolts, and lowering the temperature too rapidly causes deep fractures in the firebrick.

Also, look for signs of mechanical strain caused by poor operation of the boiler. Continued panting or vibration of the boiler can cause a weakened section of the wall to be dislocated so that the bricks fall out onto the furnace floor. Improper oil-air ratio is the most common cause of boiler panting and vibration. Proper operation of the boiler, with particular attention to the correct use of the burners and forced draft blowers, generally prevents panting and vibration of the boiler.

Inspection should also be made of the lower side of the floor pan. Any overheating indicates a loss of insulation and excessive heat penetration. Under normal conditions, the brickwork in a boiler should last for a number of years without complete renewal.

Expansion joints should be inspected often for signs of incomplete closure. It is important to keep the joints free of grog, mortar, and refractory particles so that the joints can close properly when the boiler is fired. You can tell if an expansion joint is closing completely when it is heated by inspecting it when it is cold. If the inside of the expansion joint is light in color when the furnace is cold, the expansion joint is closing properly. If an expansion joint does not close properly when heated, the inside is dark and discolored.

The same method can be used to tell if cracks in refractory materials are closing properly when the furnace is fired. If the cracks are dark, showing that they do not close, they should be repaired.

Since the first firing of a plastic or castable burner front does more damage than any other single firing, the first inspection after installation is a very important one. The unfired burner front may appear to be in perfect condition while actually containing defects of material or workmanship that will show up immediately in the first firing.

After the boiler has steamed for several hours, slabs of plastic about 1/2- to 1-inch thick may separate from the burner's front surface and fall off. This is because the surface layer is more densely rammed during installation than the remainder of the material.

Radial cracks in the burner fronts may be found on the first inspection. These cracks are not harmful. They are caused by stresses resulting from the normal expansion and contraction of the refractory as it is heated and cooled. After the radial cracks occur, the stresses are relieved and there should be no further cracking of this type.

The cracks that eventually result in extensive damage run approximately parallel to the surface of the burner front, and they are called parallel cracks. Parallel cracks usually appear at or slightly behind the leading edge of the bladed cone. They are not dangerous until they actually loosen pieces of the burner front. Improper installation and boiler operation are usually the cause of parallel cracking.

A slanting crack in the narrow section between the burners sometimes joins a radial crack. When this occurs, pieces of plastic tend to break off. This type of damage can usually be repaired by a plastic patch.

If during your inspection you find that a castable burner front is breaking up after very little service, it is likely that too much water was used in mixing the material during installation. Sometimes the material is already partially set before installation; a common cause of this trouble is that the castable material, while in storage, reacted with moisture in the air and started to set. When castable material sets before it is used, it can never reach full strength.

Castable material is also subject to spalling after several hours of service. The peeling material, usually in 1/8-inch strips, should not be removed unless it is in the burner cone and is interfering with combustion.

If a castable front is chalky or crumbly, find out how deep the condition goes. If no more than the surface can be rubbed off, the burner front is not seriously damaged. Do not remove the crumbly material. The condition is serious only if the burner cone is affected or if the casing shows signs of overheating.

Burner tile should be inspected for loose segments and broken pieces that might cause improper cone angles. The broken or damaged segments can be repaired by patching with plastic fireclay refractory. In some cases a new segment of tile can be installed.

When you inspect boiler refractories, it is a good idea to keep in mind the possibility that damage may occur because of operational problems. Although boilers must occasionally be operated under very severe and damaging conditions, a lot of damage to refractories (and, in fact, to other boiler parts as well) is caused by poor operating procedures that are really not necessary under the circumstances. It may be helpful to show operating personnel any refractory damage that appears to be directly related to poor operation of the boiler.

Tube Inspection

When inspecting the exterior of boiler tubes, look for signs of warping, bulging, sagging, cracking, pitting, scaling, acid corrosion, and other damage. All tube sheets should be inspected for signs of leakage, especially the superheater tube sheet.

Inspection of boilers sometimes shows an unexpected condition in which adjacent boiler tubes are warped in such a way that they touch each other. When this condition exists, the tubes are said to be married. Tube marriages can result either from overheating of the tubes or from stresses developed in the tubes during installation. For the latter reason, newly erected boilers and boilers that have been retubed should always be inspected for tube alignment after the initial period of steaming.

When inspection reveals one or more tube marriages, the decision as to whether or not the married tubes should be renewed should be based on the following considerations:

1. If the tube marriage occurs in screen tubes 1 1/2 inches or larger, or if the furnace side wall or rear wall tubes are bowed, tube replacement is usually required.
2. If 1-inch or 1 1/4-inch tubes in the main bank of generating tubes are married, replacement is usually not required if the tube joints are tight under hydrostatic test.
3. Inspect the external surfaces of the tubes. If they show blistering or other signs of overheating, the tubes should be renewed.
4. Inspect the watersides. Where tube marriages exists, a poor waterside condition may indicate hard scale or oil within the affected tubes. If hard scale or oil does exist, the married tubes should be replaced, and all appropriate steps should be taken to remove the scale or oil from the rest of the boiler. If the condition of the tubes is uncertain, or if a large number of tube marriages have occurred, remove one or more sample tubes, split them, and examine them carefully.
5. Tube marriages may cause gas laning, and gas laning, in turn, may cause local overheating of the inner casing, the bottom part of the economizer, and other parts. Inspect the boiler carefully for signs of local overheating that might have been caused by gas laning resulting from the tube marriages. If the local overheating from this cause is found, renew the married tubes.

6. On single-furnace boilers, a lane more than 1 1/2 inches wide may allow overheating of the superheater and of the superheater supports. If a large lane (1 1/2 tubes wide or wider) exists near the superheater outlet header end of the boiler, the married tubes that caused such a large lane should be renewed.

To identify the cause of the tube failure by visual inspection, you will need to know something about the various ways in which tubes rupture, warp, blister, and otherwise show damage. Tube failures must be reported, and they must be reported in standard terminology. The following sections of this chapter deal with the inspection techniques required for determining the causes of tube failure and with the various ways in which boiler tube damage is classified and identified.

The inspection techniques required for determining the cause of tube failure must naturally vary according to the nature of the problem. For example, a rupture in a fire row tube can usually be described adequately on the basis of simple visual observation, but the cause of damage to a tube that is deep in the tube bank cannot usually be determined without removing the intervening tubes. When a blistered tube suggests a waterside deposit, the nature and extent of the deposit can be determined only by removing and splitting the tube so that the waterside can be examined.

Relatively simple equipment is required for the field inspection of damaged or fouled pressure parts. Equipment for this purpose should include the following: (1) devices for measuring tube diameters, depth of pits, and thickness of deposits; (2) instruments for separating deposits and corrosion products—a sharp knife, a chisel, a steel scribe, or a vise to crack deposits loose from the tube samples; (3) an approved type of portable light; (4) a supply of clean bottles for collecting samples of deposits; and (5) a mirror for viewing relatively inaccessible places.

Many of these items of equipment can be improvised if necessary. For example, a simple gauge for measuring the depth of waterside pits may be made by pushing a straight pin or a paper clip through a 3- by 5-inch card so that the point of the pin or clip projects beyond the card, at right angles to the card. Such an improvised depth gauge is shown in figure 12-8. A section of string can be wrapped around a deformed tube and then laid along a ruler to obtain a measure of tube enlargement or tube thinning. Of course, special tools such as calipers, depth gauges, and scale thickness indicators give more accurate results and should be used if they are available; but the improvised tools, if used with care, can also give good results.

The classification of boiler tube damage is considered here under four major classifications: (1) fireside cavities and scars, (2) waterside cavities and scars, (3) tube deformities and fractures, and (4) tube deposits.

FIRESIDE CAVITIES AND SCARS on the tube firesides often indicate the reasons for tube failure. The term *circumferential groove* is used to describe the metal loss that occurs in bands or stripes around the circumference of a tube. Fireside grooving of this type often occurs at the header ends of horizontal tubes such as superheater tubes. The most common cause of this damage is leakage from tube seats higher in the tube bank. The grooving occurs as the water runs

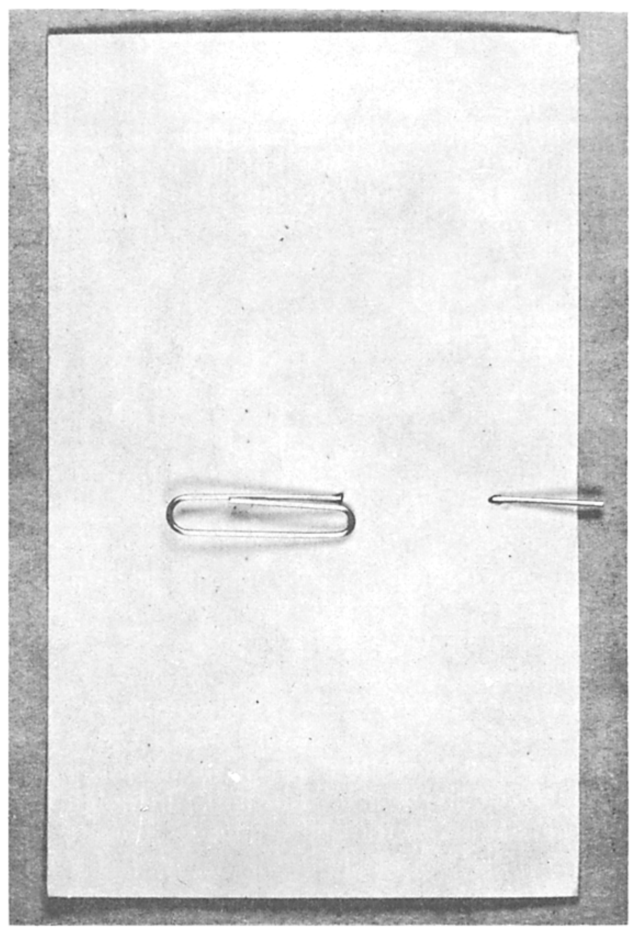

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Figure 12-8.—Improvised depth gauge.

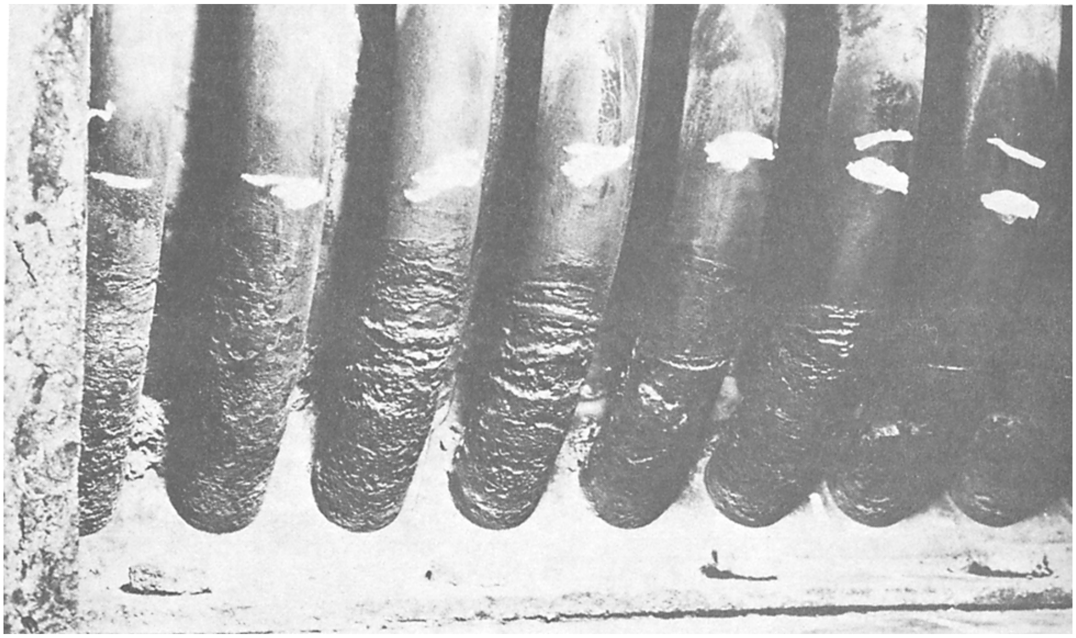

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Figure 12-9.—General fireside circumferential grooving.

down the header and onto the tube ends, or as it drips directly onto the tubes. This kind damage is greater on the top of the tube than on the underside, but the groove may extend the entire circumference.

Fireside circumferential grooving may also occur on vertical generating tubes as a result of thin, damp deposits of soot on horizontal drums or headers. In fact, this kind of grooving can occur in any part of the boiler where leakage provides a sufficient supply of water. Large quantities of water trapped between the water drum and the boiler casing—as, for example, from a serious economizer leak—can produce general fireside grooving around the bottom of the rear generating tubes. An example of this general fireside circumferential grooving is shown in figure 12-9.

CRATERS are deep, irregular, straight-walled cavities in the tube metal. WATER TRACKS are closely related to craters; the tracks consist of wandering, straight-walled, canyon-like cavities in the tube metal. Both cratering and water track-ing occur almost exclusively at the header ends of water wall tubes and division wall tubes that are surrounded by refractory; they are caused by water becoming trapped between the tube metal and the surrounding refractory. Water washing of boiler firesides, without proper drying out, is a frequent cause of cratering and water tracking; of however, any leak higher in the boiler can also cause this type of damage. The size of the leak around and the angle of the tube upon which the water leaks determine, to a large extent, whether the resulting damage will be circumferential groov-ing, cratering, or water tracking. Both cratering and water tracking are shown in figure 12-10. GENERAL FIRESIDE THINNING consists of a uniform loss of metal over a relatively large area on the outside of the tube. Soot corrosion is by far the most common cause of general fireside thinning. The parts that are particularly subject to this kind of damage are superheater

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Figure 12-10.—Fireside catering and water tracking.